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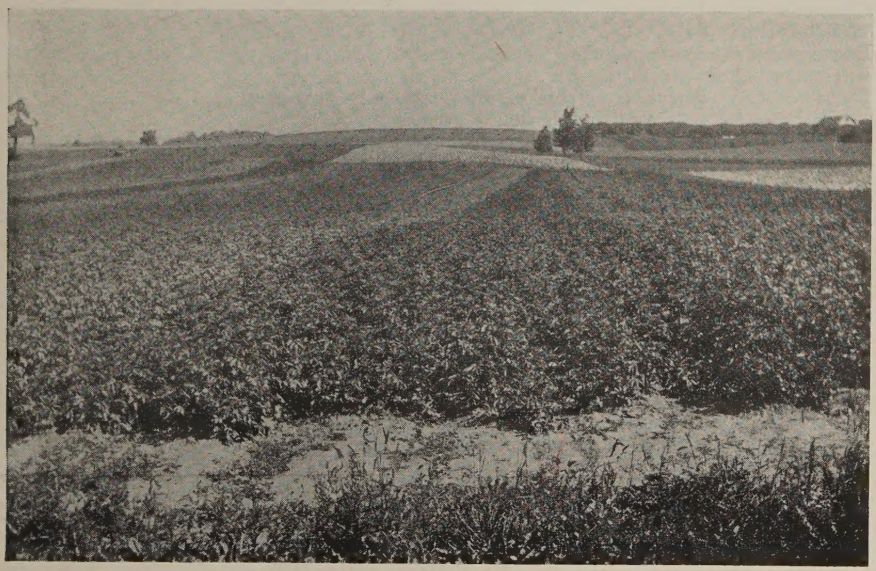
Effects of Modifications of the Potato-Spray Program

E. O. Mader and F. M. Blodgett



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EFFECTS OF MODIFICATIONS OF THE POTATO-SPRAY PROGRAM

E. O. Mader and F. M. Blodgett

Since the time of the extensive series of experiments by Stewart and others, (1912)[1] which showed beyond doubt that potato spraying pays, many questions have been raised about how the potato-spray programs can be improved. For this reason a series of experiments was started in 1929 at Pittsford in western New York to obtain additional information. These experiments were designed to determine:

(1) the most favorable pressures.
(2) the optimum seasonal distribution of copper sulfate applied as spray or dust.
(3) the effect of applications of bordeaux mixtures of various formulae.
(4) the comparative value of different amounts and kinds of lime used in making bordeaux mixture.
(5) the effect of spraying and dusting on the shape and size of tubers.
(6) the relative effectiveness of dusting as compared with spraying.

Certified Rural Russet potatoes were used unless otherwise stated. The experiments were made on three farms at Pittsford; the owners were William and Melville Miller, George and Grant Schoen, and William Schoen.

To avoid repetition of the description of the methods followed, in connection with each experiment, a general account of the methods and plans will be given here. Only such changes in plans as were peculiar to the individual experiment need additional discussion.

SPRAYING AND DUSTING EQUIPMENT

During the first year of these experiments a power sprayer manufactured by the Elmira Field Force Pump Company was used. Since that time, for the sake of accuracy in maintenance of a pressure up to 600 pounds and with capacity sufficient to supply a six-row boom with three nozzles per row, a special power sprayer (12 horse power) made by the John Bean Manufacturing Company was used. The nozzle discs of this sprayer were selected and calibrated to discharge the desired amounts in the various experiments. For all dusting experiments a traction duster manufactured by the Niagara Sprayer and Chemical Company was used.

SPRAY MATERIALS AND PRESSURES

In experiments to determine pressures that would give maximum yields, the pressures employed ranged from 200 to 600 pounds to the square inch. In all the other spray experiments a constant pressure of 400 pounds was maintained. Three nozzles to the row were used in all experiments.

[1]Potato-spraying experiments were carried on from 1896 to 1915 at the New York State [Geneva] Agricultural Experiment Station. These are described in the following bulletins published by that Station: 101, 123, 221, 241, 264, 279, 290, 307, 311, 323, 338, 349, 379, 405. 1896–1915.

The standard bordeaux mixture was made from 10 pounds of crystalline copper sulfate, 13 pounds of hydrated lime, and 100 gallons of water. This is equivalent to the 5–5–50 formula in which the second 5 refers to stone lime. Other formulae used will be given directly under the specific experiments. In making the bordeaux mixture, the copper-sulfate solution was dissolved with nearly the total amount of water and then the concentrated lime suspension added while the mixture was being agitated. In the dusting experiments, where home-mixed dust was used, the standard mixture consisted of 20 pounds of monohydrated copper sulfate and 80 pounds of hydrated lime. Calcium arsenate for control of the Colorado potato beetle was added directly to the bordeaux mixture at the rate of 2 pounds to 50 gallons or to the copper-lime dust. All untreated plots received corresponding amounts of calcium arsenate applied with a hand duster.

PLAN OF EXPERIMENTAL PLOTS

A plan for the experiments was adopted in which the plots were half the width of the sprayer, i.e. 3 rows in width, and the length of the field. The plots were arranged to keep the essential features of the "half-drill strip" method described by E. S. Beaven of Warminster in the *Journal of the Minister of Agriculture* (Journ. 29: 4, 5. 1922) for testing cereal varieties. In its simplest form where two methods of spraying were compared, if these are called *A* and *B*, the arrangement was: AB BA AB BA, and so on. In all the experiments where more than two methods were compared they were essentially based on this arrangement. If various amounts of liquid were applied at the same pressure the nozzle arrangement was varied on the two sides of the sprayer boom. The arrangement of the plots would be as follows: 1S, 1L, 2S, 2L, 3S, 3L, etc. where S stands for small and L for large nozzle orifice. In these arrangements the order of the plots is reversed in each successive pairing so that any variability of soil, or fungus, or insect infestation in one direction across the field does not continually appear to favor one treatment or the other.

TESTS FOR COPPER TO DETERMINE ADHESION

Analyses of sprayed or dusted leaves for copper were made at frequent intervals. The amounts of copper on the plants in the different series of plots could then be compared with the amounts of various insect and fungus injuries found throughout the season. The analyses also served as direct measurements of the adhesiveness of the different mixtures being compared, either dust or spray, bordeaux mixture made with different kinds of lime, or different ratios of copper to lime. The method used was that described by Winston and Fulton (1919) or the modification described by Boyd (1926) except a colorimeter was used in making comparisons with the standard solutions. Leaf samples were taken for analyses before and after each application. The method of sampling leaves for copper analyses was to walk through each series of plots collecting a few leaflets at frequent intervals from the outside of the plants at about two-thirds of their height. Leaves taken at random from various parts of the plants gave erratic results because of varying amounts of soil on the lower leaves and the fact that the top leaves of rapidly growing plants were small when treated. Analyses of such composite samples were often influenced more by the rate

of growth of the plant than by the adhesiveness of the spray. From a large sample, three sub-samples of 100 grams each were weighed out for copper analyses.

METHODS OF MEASURING GROWTH OF PLANTS AND INJURIES CAUSED BY INSECTS AND DISEASES

TOTAL HEALTHY AND TIPBURNED LEAFLETS PER PLANT

Counts of total, healthy, and tipburned leaflets per plant were made at intervals during the season to study the effect of copper on the growth of the plants and to estimate the relative control of the various insects and diseases encountered. The counts were made for plants selected at random, in units of ten in comparable locations, to warrant statistical treatment of the data. A leaflet was considered tipburned when one-eighth of its surface was dead or inactive. No attempt was made to differentiate between injuries caused by leaf-hoppers and similar defects attributable to other agencies for the reason that at present satisfactory methods are lacking to separate them.

FOLIAGE AND TUBER WEIGHTS, AND SHAPE AND SIZE OF TUBERS

As another measure of the relative growth of plants during the season, units of ten plants were selected at comparative places in the replicated plots. The green tops were weighed separately immediately on removal from the plots. Collection of these samples began as early as the middle of August, and subsequent samples were taken at intervals of ten to fourteen days as the season advanced. The tubers were classified as to shape and size to study the effect on them of the various treatments.

METHODS OF TAKING FINAL YIELDS OF TUBERS

Tuber yields were taken on single rows of sufficient length to constitute an area of 1/100 acre. This area was chosen somewhat arbitrarily as being large enough to give a fairly low standard deviation of differences in yields between adjacent plots and as a convenient fractional part of an acre. The usual practice was to mark off a rectangular area across all the plots of sufficient length for the individual rows to comprise 1/100 acre in area. The plots were then dug with a potato digger and the potatoes from two of the three rows that comprised each half-sprayer strip were weighed separately for the comparisons.

COMPUTATION AND STATISTICAL TREATMENT OF RESULTS

In making comparisons between yields or counts for different treatments, either differences between each two treatments for each block or replication were averaged for an experiment or series of experiments, or the "analysis of variance"[2] method was used. In both methods rows with a like amount of sprayer injury were selected for comparison. Thus by either method the variance due to blocks and to differences in the amount of wheel injury between rows in sprayer strips was eliminated in computing variance due to treatments or errors in differences.

Two types of tables have been used in summarizing the yield data; in one average total yields for the different treatments in the various experiments

[2]Statistical methods for research workers, page 283. By R. A. Fisher. 1930.

are given, and in the other average differences in yields between each pair of treatments for a series of experiments. Discrepancies are fairly common but not very important between these two sets of tables. These discrepancies arise mainly from the fact that in selecting plots for comparison in averaging differences for the second set of tables, those nearest each other and having the same amount of wheel injury were paired and differences taken for averaging. Where there were more plots of one treatment than of another not all were used, and where the plots were not arranged symmetrically the same plots were not used in all sets of comparisons. In the first set of tables, on the other hand, the yields of all of the plots of a given treatment were used to give the average yield for the experiment.

CHARACTER OF SOIL IN PLOTS

All experiments were conducted on soils of the Ontario gravelly sandy loam and Ontario loam types. These soils are relatively alkaline, the pH being 7.5 or above.

WEATHER CONDITIONS

In each of the five years there was sufficient rain in the spring to give the potatoes a good start, but during July and August the weather was too dry for their best development. This was especially true for 1929, 1930, and 1933, and to some extent for 1931. In 1929, irregularities in frost injury masked the effect of the spraying and dusting in one experiment.

DISEASES AND THEIR PREVALENCE

Owing to prevailing dry weather during these years, fungus diseases were almost entirely absent. Traces of early blight caused by *Alternaria solani* (Ell. and Mart.) Jones and Grout were found, but there was never enough to cause any appreciable injury. Late blight caused by *Phytophthora infestans* (Mont.) D. By. was entirely absent for four years and occurred only in the concentration experiment late in the growing season of 1933. Only plants of untreated plots were infected. The amount of damage in the check plots was but slight since these plants were practically dead at the time the disease appeared.

INSECTS AND THEIR PREVALENCE

During the five years of the experimental work there was only a slight infestation of leaf-hoppers and flea-beetles. Although present they caused no appreciable injury during the fore part of the season. With the advance of the growing season the amount of tipburn increased, possibly caused by these insects or perhaps by drought, physiological factors, and the maturity of the plants.

Aphids were present but never were troublesome. Colorado potato beetles present in the fore part of the season were easily controlled by two or three applications of calcium arsenate and practically no injuries from these pests were recorded.

EXPERIMENTS TO DETERMINE THE EFFECTS OF DIFFERENT SPRAY PRESSURES

These experiments were planned to determine how much advantage there is in spraying at high pressures. However, changes in pressure cause

changes in distribution of spray and in the amounts of material applied. For this reason, in many of the experiments, nozzles with two sizes of disk orifices were used. These were chosen so that one set gave comparisons between the same amounts of material applied at different pressures and the other set gave comparisons of different pressures with the same size nozzle orifices but applying more material as the pressure was increased (table 7).

RELATION OF PRESSURES TO ADHESION OF COPPER

In summarizing these results for all the experiments it was found that there was a greater accumulation of copper on leaves where more material was applied, either by increasing the pressure or the size of the nozzle orifice (table 1). Where the same amount was applied at different pressures it apparently adhered better when applied at the higher pressure. Plants sprayed at higher pressures showed a greater accumulation of copper particularly toward the end of the season which might be explained on the basis of a better distribution of the material. Results of leaf prints (Blodgett and Mader, 1934) made from leaves sprayed at various pressures confirmed this conclusion.

In 1929 analyses of leaves were made to determine the effectiveness of high pressures in covering the lower central portion of the plants, as measured by the amount of copper present. Tests were made before and after the third, fourth, and fifth applications while the plants were standing upright and of almost uniform size. The results (table 2) show very clearly that more copper is present in the lower parts of the plant sprayed at higher pressure than if the same amount of material is applied at a lower pressure.

EFFECT OF DIFFERENT PRESSURES ON GROWTH OF PLANTS

It was found when comparing plots sprayed at 200, 400, and 600 pounds, that the number of leaflets per plant increased with the pressure. This increase in leaflets also occurred with the increasing amounts of material applied at the same pressure. The results of leaflet counts for 1932 (table 3) illustrate this point.

In these experiments with pressures a consistent decrease in the amount of leaf-hopper-burn has been found with increases in the amounts of bordeaux mixture applied. The results, presented in table 4, seem to indicate clearly that better control was obtained at higher pressures, but with each successive increase in pressure the decrease in leaf-hopper injury became smaller so that little advantage is gained by increasing the pressure above 400 pounds and applying 100 gallons to the acre.

Total foliage and tuber weights for forty plants of each treatment, taken at intervals during the season of 1932 (table 5), show that with increasing pressure and amounts of material applied there was an increase in foliage weight of the plant. Tuber weights reached a maximum where approximately seventy pounds of copper sulfate was applied at 400 pounds pressure. Plants receiving applications of large amounts of material at high pressures increased more rapidly in their growth and lived longer than did those that received less material at lower pressures.

The classification of tubers dug on September 28, 1932 (table 6) shows a relatively uniform tuber size and the highest total tuber weight in treat-

ments where a pressure of 400 pounds was used. Increasing pressures (more than 400 pounds) as well as increasing amounts of materials applied tended to give tubers of more uneven shape and size. Tubers in unsprayed plots were relatively uniform but total tuber weights were too small compared with sprayed plots to give promising final yields.

EFFECT OF DIFFERENT PRESSURES ON FINAL YIELDS OF TUBERS

The influence of pressures and amounts of material have been consistent throughout the four years in which these experiments have been continued. It will be observed, in table 7, that all sprayed plots consistently outyielded the unsprayed. Also, the highest yields in the sprayed plots in each of the experiments were from those sprayed either at 400 pounds pressure with medium-size nozzle orifices or at 600 pounds pressure with small nozzle orifices, both applying approximately the same amount of material.

Analysis of the yields (table 7) shows that both pressure and the amounts of material applied have an effect on yield.

Thus with smaller nozzle-orifice size the yields increased with each increase in pressure up to 600 pounds. A greater increase in yields was obtained by increasing the pressure from 200 to 400 pounds than by further increasing it from 400 to 600 pounds, affording an illustration of the law of diminishing returns which might be expected to apply in this instance.

With larger nozzle orifices, applying a larger amount of spray to the acre, no increase in yields was obtained by raising the pressure above 400 pounds. Increasing the size of nozzle orifices, and in that way the amount of spray applied to the acre, gave larger yields at both 200 and 400 pounds pressure, although in this instance the law of diminishing returns also appeared to operate. That is, the increase in yields, as a result of using large nozzle orifices as compared with the small, was greater at 200 pounds than at 400 pounds, and at 600 pounds pressure a slight decrease was recorded.

TABLE 1. COMPARISON OF THE ADHESION OF BORDEAUX MIXTURE TO POTATO FOLIAGE WHEN APPLIED IN DIFFERENT AMOUNTS AND AT DIFFERENT PRESSURES, PRESSURE EXPERIMENT OF 1931

Date of application	Date of sample	Quantities of copper per 100 grams of leaves					
		Pressures and amounts of material used					
		200 lbs. 71 gals.	200 lbs. 116 gals.	400 lbs. 100 gals.	400 lbs. 116 gals.	600 lbs. 116 gals.	600 lbs. 125 gals.
		Milligrams	*Milligrams*	*Milligrams*	*Milligrams*	*Milligrams*	*Milligrams*
July 8	July 8	17.6	31.8	25.9	35.8	34.1	39.1
	July 16	5.9	13.5	9.7	11.9	11.9	15.2
July 17	July 17	33.3	48.7	38.9	50.5	54.1	56.6
	July 29	8.1	18.3	11.8	14.4	19.1	20.7
July 30	July 30	38.6	51.7	57.2	61.9	81.1	96.9
	Aug. 11	16.5	22.5	29.9	37.6	45.4	52.4
Aug. 12	Aug. 12	43.9	57.3	57.6	71.9	92.1	106.5
	Aug. 23	34.3	49.9	48.5	62.2	67.3	74.3
Aug. 24	Aug. 24	69.9	87.2	102.5	115.3	131.6	137.6
	Sept. 4	40.1	55.5	60.8	93.7	99.1	104.5
Sept. 5	Sept. 5	86.4	112.6	125.9	144.1	147.9	160.0
	Sept. 16	42.2	59.4	73.4	102.3	110.4	120.2
Sept. 19	Sept. 19	91.3	120.8	139.2	150.9	152.3	173.6

TABLE 2. AMOUNTS OF COPPER OBTAINED FROM ANALYSES OF LEAVES FROM THE LOWER CENTRAL PARTS ONLY OF PLANTS IN THE PRESSURE EXPERIMENT OF 1929

Date of application	Date of sampling	Quantities of copper per 100 grams of leaves		
		Pressure and amount of material used		
		200 lbs. 77 gal. per acre	200 lbs. 108 gal. per acre	400 lbs. 108 gal. per acre
		Milligrams	*Milligrams*	*Milligrams*
Aug. 6	Aug. 6	15	20	32
	Aug. 17	10	15	25
Aug. 19	Aug. 19	20	30	40
	Aug. 29	14	19	26
Aug. 30	Aug. 30	22	38	50
	Sept. 10	18	24	38

TABLE 3. AVERAGE NUMBER AND CONDITION OF LEAFLETS ON PLANTS SPRAYED AT DIFFERENT PRESSURES, AVERAGES OF TEN COUNTS AT PITTSFORD IN 1932

Dates of counts	Unsprayed*		200 pounds*		400 pounds*		600 pounds*	
	A	B	A	B	A	B	A	B
July 18	...	176	...	174	...	183	...	188
July 28	...	199	...	250	...	268	...	271
Aug. 8	11	324	5	369	4	432	4	453
Aug. 22	73	638	50	641	25	703	22	763
Sept. 6	507	757	333	837	211	1,045	202	1,141
Sept. 21	583	613	662	827	605	993	580	1,041
Oct. 4...	539	539	553	606	745	885	804	1,002

*A = tipburned
B = total.

TABLE 4. SUMMARY OF COMPARISONS BETWEEN SPRAYED AND UNSPRAYED PLANTS TO SHOW DECREASES, PER PLANT, IN NUMBER OF HOPPER-BURNED LEAFLETS DUE TO SPRAYING AT DIFFERENT PRESSURES, EXPERIMENTS CONDUCTED AT PITTSFORD, NEW YORK, 1929–1931

Pressure	Quantity per acre per application	1929		1930				1931		Average decreases
		Counts	Decreases	Exp. I		Exp. II		Counts	Decreases	
				Counts	Decreases	Counts	Decreases			
Pounds	*Gallons*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*
200	71*	50	113.3	50	111.0	50	113.3	50	98.6	109.0
200	116†	50	174.2	50	146.1	..	....	50	124.6	148.3
400	100†	50	195.8	50	148.7	50	165.0	50	148.6	164.5
400	116	..	....	50	156.0	..	....	50	155.2	155.6
600	116	..	....	50	161.0	50	178.8	50	158.3	166.0
600	125	..	....	50	157.8	..	....	50	157.2	157.5
Average hopper-burn on untreated plants		50	223.6	50	201	50	226.8	50	226.8	219.6

*77 gallons in 1929.
†108 gallons in 1929.

DISCUSSION OF RESULTS

With only moderate injury caused by leaf-hoppers and flea-beetles, the differences in yields obtained can be explained but partly on the basis of controlling these pests. Increasing the pressure as well as the amounts of material applied increased the foliage growth. A substantial increase in foliage usually was accompanied by an increase in the yields but the application of very large amounts caused continued growth late in the season and gave a large percentage of abnormally shaped tubers.

It should perhaps be emphasized that these results were obtained in western New York with Rural potatoes. There are indications that pressure and amounts of spray applied are not so important with Green Mountains as was indicated by Blodgett and others (1933) for Long Island, and

TABLE 5. FOLIAGE AND TUBER WEIGHTS OF PLANTS IN EXPERIMENTS WITH DIFFERENT PRESSURES, 1932, TOTAL FOR 40 PLANTS

Date of sampling	Check	Pressure in pounds per square inch: 200	400	600	Error
		Total amounts of copper sulfate per acre per season: 49.7 pounds	70.0 pounds	87.5 pounds	
Foliage weights					
		Pounds	*Pounds*	*Pounds*	
Sept. 6	34.76	35.76	45.07	47.01	4.31
Sept. 16	31.89	35.51	44.26	46.44	3.96
Tuber weights					
		Pounds	*Pounds*	*Pounds*	
Sept. 6	32.82	34.57	44.07	45.50	2.59
Sept. 16	37.38	40.63	51.14	48.76	2.62
Sept. 28	39.56	50.37	60.94	59.38	2.80

TABLE 6. YIELDS AND SIZE GRADES OF TUBERS IN THE PLOTS SPRAYED AT DIFFERENT PRESSURES, SEPTEMBER 28, 1932

	Check	Pressures in pounds per square inch: 200	400	600
		Total amounts of copper sulfate per acre per season: *Pounds* 49.7	*Pounds* 70.0	*Pounds* 87.5
		Total yields of 40 plants		
	Pounds 41.9	*Pounds* 50.6	*Pounds* 60.2	*Pounds* 59.6
		Tubers in different size classes		
Size	*Per cent*	*Per cent*	*Per cent*	*Per cent*
1–5 cm	13	16	12	15
5–8 cm	60	53	58	56
8–11 cm	20	23	20	16
Above 11 cm	7	8	10	13

Martin (1930) in New Jersey. Tilford (1931) studying the effect of different pressures under conditions in Ohio where Rural varieties of potatoes are more commonly grown, found that bordeaux mixture when applied at 400 pounds pressure was more effective than when applied at 200 or 600 pounds.

TABLE 7. AVERAGE YIELDS IN BUSHELS PER ACRE FROM PLOTS SPRAYED AT DIFFERENT PRESSURES AT PITTSFORD, NEW YORK, 1929–1932

Pressure	Quantity per acre*	1929		1930				1931		1932	
				Exp. I		Exp. II					
		Plots	Yields per acre	Plots	Yields per acre	Plots	Yields per acre	Plots	Yields per acre	Plots	Yields per acre
Pounds	*Gallons*	*Number*	*Bushels*	*Number*	*Bushels*	*Number*	*Bushels*	*Number*	*Bushels*	*Number*	*Bushels*
Unsprayed	.....	4	240.1	8	224.3	4	195.6	12	214.7	12	224.9
200.....	71(S)	9	258.7	16	271.4	12	250.7	12	232.9	21	272.8
200.....	108†, 116(L)	9	276.8	16	284.0	..	....	12	253.8	..	....
400.....	108†, 100(S)	9	295.2	16	296.8	12	306.0	12	258.7	21	307.8
400.....	116(M)	.	....	16	306.1	..	....	11	279.0	..	....
600.....	116(S)	.	....	16	307.6	12	328.5	11	285.5	..	....
600.....	125(M)	.	....	16	304.6	..	....	12	277.5	21	279.8

Average gain in bushels per acre of treatment at side of table over treatment at top of table for the series of experiments shown above§

Pressure in pounds*	Unsprayed	Pressure in pounds*				
		200(S)	200(L)	400(S)	400(M)	600(S)
200(S)	38.2±8.4‡ (40)	.....	.....	.....	.....	.....
200(L)	45.7±7.1 (24)	16.7±2.6 (37)	.....	.....	.....	.....
400(S)	69.9±9.4 (48)	36.1±5.2 (58)	11.6±3.7 (37)	.....	.....	.....
400(M)	71.7±8.6 (19)	38.6±4.6 (27)	23.0±1.1 (27)	13.2±4.8 (27)	.....	.....
600(S)	101.2±22.6 (31)	53.4±12.7 (39)	26.5±3.6 (27)	18.0±4.8 (39)	3.5±2.5 (27)	.....
600(M)	72.0±5.2 (32)	32.5±5.5 (49)	29.1±1.5 (28)	2.9±8.4 (49)	−2.2±3.5 (27)	−5.3±2.8 (27)

*S = Small nozzle orifice L = large nozzle orifice M = medium nozzle orifice.
†Only in 1929.
‡Standard error is given; differences more than twice as large as the standard error are probably significant.
§Figures in parenthesis indicate number of comparisons.

EXPERIMENTS TO DETERMINE THE EFFECTS OF DIFFERENT CONCENTRATIONS OF SPRAY

Since it was shown in 1929 that part of the gain in yield obtained by spraying at higher pressures was due to the larger amount of material applied, the question naturally arose as to what is the optimum amount of copper sulfate in the form of bordeaux mixture to be applied to an acre in a season, to give maximum yields. Consequently, experiments were arranged in which varying quantities were applied in different plots at 400 pounds pressure. These varied from 24 to 144 pounds to the acre for each of the seasons of 1932 and 1933.

RELATION OF CONCENTRATIONS TO ADHESION OF COPPER

For all experiments from 1930 to 1933, analyses showed that the amount of copper on the plants was approximately proportional to the concentration of the mixtures applied. There were no great differences in the ad-

hesivness of the mixtures used. The relative adhesion of the copper for the treatments of 1932 (table 8) may serve to illustrate this point.

EFFECT OF DIFFERENT CONCENTRATIONS ON GROWTH OF THE PLANT

Total number of leaflets per plant

Early in the season no distinction was made between healthy and injured leaflets. The number of those injured was very small. From the fourth week on, the healthy and injured leaflets were recorded separately (table 9).

At the time of the first counts (July 10) no differences were detected in the total numbers of leaflets in the different treatments. Later, the plants in the 8–8–50 plots showed a larger number of leaflets to the plant which relation continued throughout the remainder of the season. Field conditions were so uniform that these differences were not apparently influenced by soil variation. The larger number of injured leaflets and possibly smaller number of total leaflets in the checks were due to leaf-hopper and flea-beetle injury. The fewer leaflets in the counts on September 8 resulted from heavy rain and hail on September 1. The rapid increase in the number of injured leaflets in the checks after September 8 was due to maturity of the plants. In the 4–4–50 and 8–8–50 plots, up to September 29, injury was largely caused by leaf-hoppers and flea-beetles while after that time the plants in the 4–4–50 plots commenced to die. Although the leaflets in the check and 4–4–50 plots were practically dead at digging time, a large number of healthy leaflets were present on plants which had received the 8–8–50 treatments. Similar counts as to the total number of leaflets per plant were made in 1931. In this season only slight differences between the growth of the plants treated with the 4–4–50 and the 8–8–50 could be noted. However, it was noticed that the small increases in growth of the plants treated with the 8–8–50 were consistent from the beginning. Counts of total leaflets for 1932 and 1933 showed similar tendencies.

Total number of tipburned leaflets per plant

All treatments resulted in less tipburn injury than the check.

In the experiments of 1932 and 1933, where the quantity of copper sulfate used varied from 24 to 144 pounds to the acre per season, there was no appreciable reduction in the amount of tipburn when more than 36 pounds of copper sulfate was used.[3]

Total green weight of foliage and tubers, and grade of tubers

The weights of foliage and tubers obtained from forty plants for 1933 are given in unpublished data[3], in which it is reported that increasing the amount of copper sulfate applied increased the foliage weights of the plants. The highest tuber weights, however, were found in plots receiving treatments of approximately 75 pounds of copper sulfate to the acre per season. The tubers in the various treatments were graded as to shape and size. The results of this grading may be summarized as follows: the largest percentage of uniform tubers (average size 5–8 centimeters) was in the plots which had received from 50 to 75 pounds of copper sulfate to the acre per season. Plots which had received greater and smaller quantities of copper sulfate

[3]Thesis, by E. O. Mader, in preparation.

tended to give tubers of a more uneven shape and size. Tubers in untreated plots were relatively uniform, but the total tuber yields were low as compared with those from sprayed plots.

EFFECT OF CONCENTRATIONS ON FINAL TUBER YIELDS

The influence of amounts of material has been consistent throughout the four years of these experiments (table 10). All sprayed plots show a substantial gain over the unsprayed. With increasing quantities of copper up to 75 pounds of copper sulfate to the acre per season the tuber weight increased, followed by a gradual decline in yields with larger applications.

DISCUSSION OF RESULTS

All the differences obtained were uniform and it is apparent that the increased yields were not all due to protection from insect pests since no better protection was obtained when the quantity of copper sulfate applied was increased beyond 36 pounds per acre per season. Differences in the growth of the plants in the various treatments seem to account for the differences in yields obtained. Plants treated with the high-copper concentration not only reached an earlier maximum in their growth, but remained green longer at the end of the season.

A consideration of these factors seems to indicate that the larger quantities of copper may have stimulated top growth at the expense of tuber formation. A similar explanation would seem to apply in the pressure experiment where liberal quantities were applied at 600 pounds pressure. Plots receiving applications of around 75 pounds of copper sulfate to the acre per season also produced the best grade of tubers.

Although no definite statements as to the effect of various amounts of copper sulfate on potato yields were found in the literature, the results of Cook (1923) are of interest. In comparing a 10–10–50 with a 5–5–50 at the Arlington Experimental Farm, Virginia, he found that the former spray had no advantage over the latter and "may possibly furnish too much copper for the maximum stimulating or protective effects." In another experiment by the same worker in New Jersey, a 4–4–50 bordeaux mixture applied eight times gave no increased yields over the same spray applied four times. Although the quantities of copper sulfate to the acre per season are not given, there is indication that Cook found in these experiments that the effect of copper on potato yields had a tendency similar to that obtained here for he states that large quantities of copper such as a 10–10–50 have no advantage over smaller quantities such as a 4–4–50. He suggests that there must be an optimum amount which produces the highest yields. That the amount of spray applied is an important factor was indicated by the results of single and double spraying experiments which were widely scattered in New York State (Stewart and others, 1912).

The use of about 75 pounds of copper sulfate as a total to the acre per season is not to be considered as the universal optimum quantity for all spraying regardless of location and varieties used. The results of experiments under conditions on Long Island indicate that the total amount applied which gives optimum yields lies about 30 to 40 pounds with the Green Mountain variety as compared with 75 pounds for Rural Russets in western New York. (Blodgett and others, 1933).

TABLE 8. COMPARING THE ADHESION OF BORDEAUX MIXTURE AT DIFFERENT COPPER CONCENTRATIONS AND AMOUNTS AT 400 POUNDS PRESSURE, 1932

Date of application	Date of sample	2–2–50 100 gal.	2–2–50 154 gal.	4–4–50 100 gal.	4–4–50 154 gal.	8–8–50 100 gal.	8–8–50 154 gal.
		Pounds of copper sulfate applied per acre per season					
		24.0	36.9	48.0	73.9	96.0	144.8
		Quantities of copper found on 100 grams green leaves					
		Milligrams	*Milligrams*	*Milligrams*	*Milligrams*	*Milligrams*	*Milligrams*
July 15	July 15	14.8	19.7	29.7	41.4	60.7	68.7
	July 22	7.7	11.4	15.3	17.9	28.6	32.0
July 25	July 25	23.4	33.1	45.5	50.5	81.5	90.9
	July 29	11.4	15.7	23.3	27.0	44.9	48.9
July 30	July 30	29.0	38.8	48.8	57.5	84.5	100.8
	Aug. 7	19.3	27.1	37.9	47.1	57.1	73.2
Aug. 8	Aug. 8	34.5	44.7	65.6	72.1	101.3	121.6
	Aug. 19	24.1	33.0	51.5	64.5	82.9	97.8
Aug. 20	Aug. 20	39.4	53.4	73.4	90.8	121.9	138.7
	Aug. 31	28.8	37.9	67.9	76.9	96.8	118.1
Sept. 3	Sept. 3	48.9	66.2	90.5	129.9	162.6	186.9
	Sept. 10	37.1	48.9	86.3	109.4	150.1	171.3
	Sept. 24	34.9	45.9	83.9	106.2	144.6	164.3

TABLE 9. AVERAGE NUMBER AND CONDITION OF LEAFLETS ON PLANTS IN PLOTS SPRAYED WITH 4–4–50 AND 8–8–50 BORDEAUX (AVERAGE OF 10 COUNTS)

1930

Dates of counts	Unsprayed*		4–4–50*		8–8–50*	
	A	B	A	B	A	B
	Number	*Number*	*Number*	*Number*	*Number*	*Number*
July 10	...	70	...	72	...	68
July 2	...	189	...	233	...	253
Aug. 2	...	282	...	392	...	482
Aug. 11	41	367	21	496	12	620
Aug. 27	185	453	49	639	31	759
Sept. 8	135	326	61	453	34	600
Sept. 19	251	490	91	619	67	732
Sept. 29	513	526	172	652	97	790
Oct. 4	...	...	320	645	172	810
Oct. 10	...	...	510	630	261	820
Oct. 16	...	...	...	...	380	805

1931

	A	B	A	B	A	B
	Number	*Number*	*Number*	*Number*	*Number*	*Number*
July 10	...	118	...	117	...	118
July 21	...	202	...	246	...	244
July 27	21	270	8	335	6	357
Aug. 6	32	507	10	547	9	571
Aug. 17	132	528	57	649	45	667
Aug. 31	211	694	100	700	92	737
Sept. 10	408	504	194	699	147	834
Sept. 21	308	322	312	541	202	640
Oct. 1	...	...	180	203	257	305

*A = tipburned
B = total.

TABLE 10. AVERAGE YIELD IN BUSHELS PER ACRE IN THE CONCENTRATION EXPERIMENTS AT PITTSFORD, NEW YORK AT 400 POUNDS PRESSURE

Treatment*	Quantity of material	1930		1931		1932		1933	
		Plots	Average yields per acre	Plots	Average yields per acre	Plots	Average yields per acre	Plots	Average yields per acre
	Gallons	*Number*	*Bushels*	*Number*	*Bushels*	*Number*	*Bushels*	*Number*	*Bushels*
Unsprayed	...	8	210.4	6	151.0	12	213.4	12	174.4
2–2–50 (S)	100	..	....	..	....	12	268.7	12	237.2
2–2–50 (L)	154	..	....	..	....	12	283.8	12	260.9
4–4–50 (S)	100	14	326.1	15	198.6	12	311.4	12	281.3
4–4–50 (L)	154	..	....	..	....	12	329.3	12	294.6
8–8–50 (S)	100	14	305.8	15	202.8	12	303.4	12	285.6
8–8–50 (L)	154	...	....	..	....	12	299.3	12	274.7

Average gain in bushels per acre of treatment at side of table over treatment at top of table for the series of experiments shown above†

Treatment*	Treatment*					
	Unsprayed	2–2–50 (S)	2–2–50 (L)	4–4–50 (S)	4–4–50 (L)	8–8–50 (S)
2–2–50 (S)	59.1 ±3.7 (24)	.....	.....	.....	.....	.....
2–2–50 (L)	78.5 ±8.0 (24)	19.5 ±4.4 (24)	.....	.....	.....	.....
4–4–50 (S)	96.8 ±12.8 (38)	43.4 ±0.7 (24)	24.0 ±3.6 (24)	.....	.....	.....
4–4–50 (L)	118.1 ±2.2 (24)	59.0 ±1.6 (24)	39.6 ±5.6 (24)	15.6 ±2.3 (24)	.....	.....
8–8–50 (S)	91.4 ±11.2 (38)	41.6 ±6.9 (24)	22.2 ±2.6 (24)	−5.0 ±6.0 (53)	−17.4 ±8.4 (24)	.....
8–8–50 (L)	91.8 ±8.6 (24)	32.7 ±4.9 (24)	13.3 ±0.6 (24)	−10.7 ±4.2 (24)	−26.3 ±6.4 (24)	−8.9 ±2.0 (24)

*S = small nozzle orifice
L = large nozzle orifice.
†Figures in parenthesis indicate the number of comparisons.

EXPERIMENTS WITH DIFFERENT KINDS OF LIME

When this series of experiments was started, one of the questions most commonly raised by growers was, "what kind of lime should be used in making bordeaux mixture?" This question had become insistent mainly because of the variety of advice reaching the growers from sources outside the State. Accordingly, a series of experiments was designed to determine the comparative value of different kinds of lime for spraying purposes. The kinds compared were:

(1) High-calcium hydrated lime (calcium hydroxide)
(2) Stone lime (lump, calcium oxide)
(3) Stone lime (granulated, calcium oxide)
(4) Finishing lime (mixture of about 70 per cent calcium hydroxide and 30 per cent magnesium hydroxide)

The granulated stone lime used in this experiment was the kind made by first crushing the limestone and then driving off the carbon dioxide in a rotary kiln. It slakes very fast. The bordeaux mixture made with this lime stayed in suspension very well.

EFFECTS OF DIFFERENT KINDS OF LIME ON ADHESION OF COPPER

There was no great difference in the adhesion and accumulation of the copper on plants (table 11) sprayed with bordeaux mixtures made from

the different kinds of lime. Variations between the different plots were all so small that they might easily be due to variations in sampling. In general, the slight differences present seem to be in favor of the stone lime. In making up bordeaux mixture with these different kinds of lime it was observed that the mixture made with the finishing lime (high in magnesium) had a greenish blue color in contrast to the more intense blue color of the bordeaux mixture made with high-calcium limes. Because of the greenish color, this bordeaux mixture was barely visible on the plants early in the season and only slightly so after the fourth application.

EFFECTS OF DIFFERENT KINDS OF LIME ON NUMBER OF TIPBURNED LEAFLETS

The number of tipburned leaflets in treated plots was consistently less than in the untreated. Practically no differences between various treatments were found. The average numbers of tipburned leaflets per plant in the lime experiment of 1930 (table 12) are in agreement with counts made on the rest of the experiments not presented here.

EFFECTS OF DIFFERENT KINDS OF LIME ON FINAL TUBER YIELDS

Yields (table 13) show highly significant gains for all the sprayed plots over the checks. Differences in the treatments seem to be in favor of the finishing lime, at least in the two experiments of 1931. In all experiments the stone lime gave slightly higher yields than the hydrated, but in only one did the difference appear to be significant.

DISCUSSION OF RESULTS OF TESTS WITH DIFFERENT KINDS OF LIME

The average effect on yields of the kind of lime used in making bordeaux mixture was relatively small as compared with the other factors influencing the results of spraying. No differences in the amount of tipburn were noted. As the magnesium in the finishing lime does not react with the copper sulfate to any considerable extent, about one-third less active lime is being

TABLE 11. A COMPARISON OF THE ADHESION OF BORDEAUX MIXTURE PREPARED FROM DIFFERENT KINDS OF LIME*

Date of application	Date of sample	Quantities of copper on 100 grams of green leaves		
		Hydrated lime, high in calcium	Stone lime, rotary kiln	Finishing lime, high in magnesium
		Milligrams	*Milligrams*	*Milligrams*
July 13	July 13	40.0	42.0	39.7
	July 17	15.6	17.3	16.0
July 18	July 18	55.0	60.6	55.3
	July 31	19.3	22.3	19.3
Aug. 1	Aug. 1	64.6	68.0	66.6
	Aug. 12	33.1	42.3	37.5
Aug. 13	Aug. 13	70.1	76.3	73.6
	Aug. 24	62.6	68.5	66.2
Aug. 25	Aug. 25	101.8	109.1	103.8
	Sept. 4	75.0	93.0	98.0
Sept. 5	Sept. 5	121.0	130.0	138.0
	Sept. 17	88.0	96.0	102.0
Sept. 19	Sept. 19	128.0	135.0	142.0

*William Schoen farm, 1931.

TABLE 12. AVERAGE NUMBER OF TIPBURNED LEAFLETS PER PLANT IN PLOTS SPRAYED WITH BORDEAUX MIXTURE MADE WITH DIFFERENT KINDS OF LIME, 1931

	Aug. 11	Aug. 27	Sept. 10	Sept. 20	Sept. 30
	Number	*Number*	*Number*	*Number*	*Number*
Unsprayed	41.9	190.7	107.1	260.2	419.2
Hydrated lime, high in calcium	21.6	35.1	46.9	76.1	136.5
Stone lime, high in calcium	19.2	32.0	44.7	72.1	118.6
Finishing lime, high in magnesium	19.4	34.7	47.4	73.8	123.2

TABLE 13. AVERAGE YIELDS IN BUSHELS PER ACRE IN PLOTS SPRAYED WITH BORDEAUX MIXTURE MADE WITH DIFFERENT KINDS OF LIME AT PITTSFORD, NEW YORK, AT 400 POUNDS PRESSURE, 1930–1931

Kind of lime used in 5–5–50 bordeaux	Quantity per acre	1930				1931			
		Exp. I		Exp. II		Exp. I		Exp. II	
		Plots	Average yields per acre	Plots	Average yields per acre	Plots	Average yields per acre	Plots	Average yields per acre
	Gallons	*Number*	*Bushels*	*Number*	*Bushels*	*Number*	*Bushels*	*Number*	*Bushels*
Unsprayed	.....	4	204.2	4	208.7	3	121.4	3	163.7
Hydrated	100*, 106	18	289.6	12	280.6	12	136.5	12	257.9
Stone, lump	100*	18	306.9	..	....	..	....	..	....
Stone, granulated	106	..	....	12	290.7	12	145.2	12	259.1
Finishing, high-magnesium	100*, 106	18	297.8	..	....	12	149.2	12	282.6

Average gain in bushels per acre of treatment at side of table over treatment at top of table for the series of experiments shown above†

Treatment	Treatment			
	Unsprayed	Hydrated lime	Stone lime, granulated	Stone lime, lump
Calcium, hydrated	74.2±21.7 (14)	.....	.....	.....
Stone lime, granulated	73.2±22.0 (10)	4.2±2.6 (42)	.....	.....
Stone lime, lump	101.5±4.7 (4)	16.7±3.7 (20)	.....	.....
Finishing, high-magnesium	84.4±25.0 (10)	13.2±5.5 (42)	13.5±9.6 (24)	−7.5±1.8 (18)

*Only in experiment I, 1930.
†Figures in parenthesis indicate the total number of comparisons.

used in this material. Thus the benefits from the use of finishing lime might come either from the effect of magnesium on the growth of the plants or from the lower ratio of active lime to copper in the mixture which might be expected to yield more soluble copper. As the soil where these spraying experiments were made was highly alkaline and believed not to be deficient in magnesium, arrangements were made to test the second hypothesis by varying the ratio of lime to copper in the spray mixture, without the magnesium, to determine whether the same effect would be obtained.

EXPERIMENTS WITH DIFFERENT COPPER-LIME RATIOS

To determine whether the lower lime content in the bordeaux mixture made from finishing lime was the factor which gave increased yields in the lime experiments, a series of experiments with variable copper-lime ratios was started in 1932. The only variable in this type of experiment was the

amount of lime in the bordeaux mixtures. Bordeaux mixtures of the following ratios were compared:

Number	Copper sulfate crystals	Calcium oxide	Calcium-oxide equivalent in hydrated lime	Water
	Pounds	*Pounds*	*Pounds*	*Gallons*
1	5.0	0.8	1.06	50
2	5.0	2.5	3.3	50
3	5.0	5.0	6.6	50
4	5.0	7.5	9.9	50

A hydrated, high-calcium lime was used, in the amounts shown in the fourth column but in the formulae in the text this is expressed as calcium oxide as given in the third column to be consistent with other formulae given in the bulletin. The colors of these bordeaux mixtures ranged from Prussian blue to green as the lime content decreased. Applications of bordeaux mixture with the lower lime content were hardly noticeable on the potato foliage compared with the thick lime coating of those containing the high lime-to-copper ratios.

EFFECT OF DIFFERENT COPPER-LIME RATIOS ON ADHESION OF COPPER

There were practically no differences in the adhesion of the bordeaux mixtures made from various copper-to-lime ratios on potato foliage. The slight variations found (table 14) were not consistently in favor of any one treatment and may be attributed to variations of sampling. No copper injury to the potato foliage was noted in either season.

EFFECT OF DIFFERENT COPPER-LIME RATIOS ON NUMBER OF TIPBURNED LEAFLETS

The degree of control of tipburn by various bordeaux mixtures as a criterion for these mixtures failed to show differences between treatments as it did in the lime experiment. For both seasons practically no differences in the number of tipburned leaflets in the sprayed plots were found. All treatments showed a consistently smaller number of tipburned leaflets (table 15) than did the check plots. When counts were made on September 23 the plants in the check plots were practically dead.

EFFECT OF DIFFERENT COPPER-LIME RATIOS ON FINAL TUBER YIELDS

With decreasing amounts of lime used in the bordeaux mixtures, the yields increased (table 16). All differences between treatments are significant with the exception of those between the 5–2½–50 and the 5–0.8–50 treatments of 1933. The lowest ratio of lime to copper gave an average increase in yield over the highest of 29 bushels to the acre and over the usual 5–5–50 formula of nearly 20 bushels per acre.

DISCUSSION OF RESULTS OF TESTS WITH DIFFERENT COPPER-LIME RATIOS

The differences in yields can hardly be explained on the basis of insect control since all the bordeaux mixtures gave equal control. Failure to obtain increases in 1933 by lowering the lime content below the 5–2½–50 ratio might have resulted from some variation in the quality of the lime used or from the fact that the growing season of 1933 was shorter than that of 1932. Plants in all of the experimental plots in 1933 died about the middle

of September, owing to lack of moisture. Since only a total of 64.8 pounds of copper sulfate was used in all these plots they can hardly be compared with the concentration experiment (page 13) where optimum yields were obtained by using about 75 pounds of copper sulfate to the acre per season. The differences in yields in favor of the lower lime mixture might be due to the greater solubility of the copper, since it was found that the copper in bordeaux mixture made with smaller amounts of lime is more readily soluble (unpublished data and Hockenyos, 1931). At any rate the ratio of lime to copper in bordeaux mixture seems to be a more important factor in obtaining higher yields than the kind of lime used for the preparation of the mixture.

The results of a similar type of experiment conducted on Long Island (Blodgett and others, 1933) are in general agreement, namely, a decrease in the lime content in the mixture was followed by an increase in yields.

Cook (1923) conducted experiments in which he found that in comparing a 4–4–50 with a 0–4–50, the latter formula containing only lime, gave yields even lower than those of the unsprayed plants.

It has been well known that the usually recommended formulae for bordeaux mixture containing as much quick lime as crystalline copper sulfate, contains a large excess of lime beyond that required for the reaction with the copper sulfate. According to the figures supplied by Martin (1932) or Hockenyos (1931), for 5 pounds of copper-sulfate crystals about eight-tenths of a pound of calcium oxide or one pound of hydrated lime is required. Half as much lime (stone lime or hydrated) as copper sulfate gives an alkaline mixture and one with sufficient excess of lime to be free from injury due to slight deterioration of the lime used. Such a mixture has recently been recommended by Rudolph (1933) in spraying to control the bacterial blight of English walnut. The two years reviewed here indicate that some increase in yield can be obtained by using this mixture with reduced lime content on potatoes.

TABLE 14. A COMPARISON OF THE ADHESION OF BORDEAUX MIXTURES MADE WITH VARYING COPPER-LIME RATIOS, COPPER-LIME-RATIO EXPERIMENT, 1932

Date of application	Date of sampling	Copper-lime ratios used			
		5:0.8	5:2½	5:5	5:7½
		Quantities of copper per 100 grams of leaves			
		Milligrams	*Milligrams*	*Milligrams*	*Milligrams*
July 14	July 14	39.2	38.6	43.6	43.5
	July 21	25.7	26.1	26.5	25.7
July 22	July 22	46.4	43.0	46.8	47.5
	July 28	37.3	37.4	38.7	40.2
July 29	July 29	59.2	62.2	60.6	61.3
	Aug. 5	41.2	40.6	41.9	41.6
Aug. 6	Aug. 6	64.9	65.5	65.2	66.6
	Aug. 15	50.9	51.2	52.1	52.6
	Aug. 17	50.7	50.5	51.1	51.9
Aug. 20	Aug. 20	73.1	73.3	74.4	74.1
	Aug. 22	66.7	68.4	68.7	69.2
	Aug. 25	63.8	67.8	65.1	65.0
	Aug. 29	61.2	61.5	62.2	62.3
	Aug. 31	60.3	61.2	61.7	61.2
Sept. 2	Sept. 2	86.9	86.8	86.0	86.2
	Sept. 4	80.9	80.5	80.9	80.6
	Sept. 9	78.3	78.5	78.2	77.8
	Sept. 16	76.6	76.3	75.9	75.2

TABLE 15. AVERAGE NUMBER OF TIPBURNED LEAFLETS, COPPER-LIME-RATIO EXPERIMENT, 1932

Date of counts	Unsprayed	Treatment			
		5–0.8–50	5–2½–50	5–5–50	5–7½–50
	Number	*Number*	*Number*	*Number*	*Number*
August 11	21	16	15	16	16
August 20	91	61	59	62	61
September 9	551	179	170	171	175
September 23	...	641	659	630	647

TABLE 16. AVERAGE YIELDS IN BUSHELS PER ACRE WITH VARIABLE QUANTITIES OF LIME AT PITTSFORD, 1932

Treatment	Quantity of material	1932		1933	
		Plots	Average yields per acre	Plots	Average yields per acre
	Gallons	*Number*	*Bushels*	*Number*	*Bushels*
Unsprayed	...	12	171.1	12	112.6
Copper-lime water 5–7½–50	106*	18	243.9	24	206.2
5–5–50	106	18	247.6	24	220.2
5–2½–50	106	18	254.7	24	238.0
5–0.8–50	106	18	270.1	24	237.1

Average gains in bushels per acre of treatment at side of table over treatment at top of table for series of experiments shown above†

Treatment	Treatment			
	Unsprayed	5–7½–50	5–5–50	5–2½–50
5–7½–50	86.9 ±6.8 (24)	.....	.....	.....
5–5–50	95.0 ±12.7 (24)	14.5 ±0.6 (42)	.....	.....
5–2½–50	107.4 ±18.0 (24)	27.8 ±4.7 (42)	18.1 ±0.4 (42)	.....
5–0.8–50	108.6 ±16.0 (24)	28.9 ±2.3 (42)	19.3 ±2.8 (42)	6.1 ±8.1 (42)

*1933, only 100 gallons per acre.
†Numbers in parenthesis indicate the number of comparisons.

EXPERIMENTS TO DETERMINE THE EFFECTS OF VARYING THE CONCENTRATION OF SPRAY THROUGH THE SEASON

It has been shown in the concentration experiment (page 13) that plants which had received large quantities of copper per application early in the season responded with a substantially larger increase in their foliage development, as compared with plants receiving less copper. A continuation of application of large quantities of copper, however, in these treatments resulted in excessive top growth at the expense of tuber formation. On the other hand, plants in the treatments which received a total of about 75 pounds of copper sulfate gave maximum yields. The phenomenon of the response of growth of plants to high copper concentrations early in the season, together with the maximum yields obtained by the use of about 75 pounds of copper sulfate, led to investigations of the effect of varying the concentration of spray during the season. A series of experiments was started in 1931. As a matter of convenience and to avoid repetition of the

various types of treatments, the schedules of applications are given. In further discussions, reference will be made to these schedules by the numbers given below.

APPLICATION SCHEDULES

Application	No. 1	No. 2	No. 3	No. 4	No. 5	Check
1st	12–12–50	1–1–50	5–2½–50	10–5–50	5–5–50	0
2d	9–9–50	2–2–50	12–2½–50	8–4–50	5–5–50	0
3d	6–6–50	3–3–50	8–2–50	6–3–50	5–5–50	0
4th	4–4–50	4–4–50	6–4–50	4–2–50	5–5–50	0
5th	3–3–50	6–6–50	3–1–50	3–1½–50	5–5–50	0
6th	2–2–50	9–9–50	2–½–50	3–1½–50	5–5–50	0
7th	1–1–50	12–12–50	1–½–50	3–1½–50	5–5–50	0

In these treatments the essential feature was that instead of applying the 75 pounds of copper sulfate at equal rates such as a 5–5–50 for each application, treatment 1 received at the beginning of the season a bordeaux mixture of a high concentration (12–12–50) and its strength was reduced with each subsequent application. Treatment 2 received these formulae in the reverse order, starting low and increasing the strength. In addition to these treatments, the lime content of the mixtures (treatments 3 and 4) was reduced since it was found in the copper-to-lime-ratio experiments (page 17) the yields decreased as the lime in the mixture increased. Otherwise, treatments 3 and 4 are similar to treatment 1 in that the larger amounts of copper are applied in the fore part of the season. All the treatments given above were used in 1933. The copper applied totaled 74 pounds for treatments 1, 2, 3, and 4, and only 70 pounds was used for treatment 5.

For the season of 1932, treatments 1, 2, 5, and check were compared. The copper applied for treatments 1 and 2 amounted to 86 pounds and for treatment 5 to 84 pounds to the acre per season. The application schedule for 1932 for treatments 1 and 2 was thus slightly modified from that given above. For treatment 5 a 6–6–50 was used for each application.

In 1931, treatments 1, 2, and check, only, were compared. The application schedule used was essentially the same as that given under treatments 1 and 2 with the exception that but six applications were made instead of seven; therefore treatment 2 received only 70 pounds of copper sulfate compared to 98 pounds for treatment 1.

EFFECTS ON ADHESION OF COPPER

The amount of copper found on the plants (table 17) followed approximately the changing concentration of the mixture applied. With the advance of the season, and the change in the concentration, the plants treated with the higher concentration at the start showed the largest amounts of copper after the fourth application after which the amount of copper found decreases. The increase of copper on the plants treated with the weaker concentrations early in the season is almost uniform up to the fifth application, followed by an increase with each successive application. There was a substantial but gradual increase of the copper found on the foliage when applied at equal rates such as a 5–5–50 or 6–6–50 per application. The results of 1931 and 1933 are similar in their tendencies. Lowering the lime content of the bordeaux mixture in certain treatments in the 1933 experiment did not affect the relative adhesion of copper to any appreciable extent.

EFFECT ON GROWTH OF PLANTS

Total number and condition of leaflets

As in the pressure experiment, counts of the total number of leaflets, healthy and injured, were made at intervals during the season. In 1930 only treatments 1, 2, and check were used. The number of leaflets tipburned (table 18) was very small at the first count and was disregarded. As early as the second count, July 24, a greater average number of leaflets per plant was noted in plots treated with the high concentration and the growth of the plants in these plots increased more rapidly than in those treated with the lower concentration (treatment 2). Early in September the plants of treatment 1 seemed to have produced their maximum number of leaflets, after which time the plants showed signs of normal dying of the leaflets. The plants of treatment 2 did not have so large a total number of leaflets per plant, but these plants kept green longer; and at digging time when practically all the plants of treatment 1 were dried up, a relatively large number of green leaves were present. That the difference in the growth rates of treatments 1 and 2 is only slightly affected by the number of tipburned leaflets is shown by the small difference in the number of tipburned leaflets (table 18). There were, however, consistently fewer tipburned leaflets in treatment 1 up to the next to the last count.

The increase in tipburned leaflets in the treatments after about September 1, 1931, is not due primarily to insect pests, but to other factors such as premature dying of the lower leaflets which were included in the counts.

Similar counts were made for the seasons of 1932 and 1933, including the additional treatments, and the results showed similar tendencies. All of the treatments with the high-copper concentrations early in the season, including those formulae which had a lower lime content in the mixture (treatments 3 and 4, 1933), affected the plants in the same manner as described above under treatment 1, 1931. Plants of treatment 5 which received equal quantities of copper throughout the season gave intermediate results.

Total green weight of foliage and tubers, and grade of tubers

For the 1932 and 1933 experiments, foliage and tuber weights of the various treatments were taken at intervals during the season. Plants which had received the larger quantities of copper in the fore part of the season regardless of the lime content of the mixture (treatments 1, 3, and 4) responded with a larger total green weight per plant than did those receiving the larger part of the copper near the end of the season. There was in the various treatments a close correlation between the total number of leaflets per plant and the total green weight of the tops. The earlier and larger increase in the foliage of plants of treatments 1, 3, and 4 had a decided effect on tuber development, for the two seasons. Plants receiving these treatments not only gave higher yields but yielded tubers of a more uniform shape and size than those resulting from treatment 2; the plants of treatment 5 were intermediate between plants of treatments 1, 3, and 4, and those of treatment 2, both in yields and in shape and size of tubers.

EFFECTS OF VARYING CONCENTRATIONS ON FINAL TUBER YIELDS

The yields for these experiments (table 19) show substantial gains for all sprayed plants over the unsprayed. The gain of the plots treated in the

beginning with the higher concentration (treatment 1) over those treated with the low concentration at the first part of the season (treatment 2) is about thirty bushels to the acre. Comparing the same treatment with plots which received equal amounts of copper throughout the season (treatment 5) there is an increase of about 23 bushels. Furthermore, the introduction of the factor of the lower lime content, together with the high concentration at the beginning of the season (treatments 3 and 4), gave results equal to those of the high concentration at the beginning of the season. All the differences between the treatments are highly significant.

DISCUSSION OF EFFECTS OF VARYING CONCENTRATIONS

The results of three years of experimental work have shown that not only an optimum amount of copper sulfate of approximately 75 pounds to the acre per season gave better results, but that the application of the larger part of this amount early in the season appears to give the best results.

Treatments receiving higher concentration at the beginning of the season (treatment 1) had a decidedly stimulating effect on the plants, resulting in an earlier maturity, larger tuber weights, and more uniform tubers than those treatments in which the copper was equally distributed throughout the season (treatment 5), as well as those which received higher copper concentrations toward the end of the season (treatment 2). Comparing the yields with the growth of the plant during the season, the indications are that a greater number of leaflets and a higher total green weight in the earlier part of the season are more favorable to the production of higher yields than keeping the plants green later in the season. The differences thus far obtained seem to be due to the time of stimulation by the bordeaux mixture in the growing cycle of the plant.[4] These results seem to explain to some extent some of the results obtained in the pressure and concentration experiments.

TABLE 17. COMPARISON OF THE ADHESION OF BORDEAUX MIXTURE TO POTATO FOLIAGE IN THE VARIABLE-CONCENTRATION EXPERIMENT, 1932

Date of application	Date of sample	Quantities of copper on 100 grams of green leaves		
		Treatments		
		No. 1	No. 2	No. 5
		Milligrams	*Milligrams*	*Milligrams*
July 14	July 14	65.2	10.2	33.6
	July 21	37.6	5.4	18.8
July 22	July 22	91.3	31.0	51.6
	July 28	61.5	23.3	39.5
July 29	July 29	131.8	44.4	70.0
	Aug. 5	81.1	33.0	50.8
Aug. 6	Aug. 6	150.5	65.4	90.8
	Aug. 17	104.7	48.0	68.0
	Aug. 19	102.0	47.2	64.8
Aug. 20	Aug. 20	142.5	85.4	108.9
	Aug. 31	128.6	72.8	87.2
Sept. 2	Sept. 2	138.0	138.1	119.8
	Sept. 15	126.6	116.3	104.8
Sept. 16	Sept. 16	131.3	170.4	134.2
	Sept. 24	111.9	148.7	114.2
Sept. 30	Sept. 30	105.9	143.6	109.6

[4]Thesis, by E. O. Mader, in preparation.

The introduction of a low lime-to-copper ratio in the bordeaux mixture combined with the high concentration at the beginning of the season (treatments 3 and 4) gave similar results to treatment 1. The low lime content in the mixture of these treatments did not show similar effects to those found in the copper-to-lime-ratio experiment where a decrease in the lime content was followed by an increased yield.

It may be that a total of 75 pounds of copper sulfate to the acre per season (as used in this experiment) is not the optimum for this mixture. This quantity has appeared to be the optimum with a 5–5–50 mixture but since

TABLE 18. AVERAGE NUMBER AND CONDITION OF LEAFLETS ON PLANTS IN PLOTS OF THE VARIABLE CONCENTRATION EXPERIMENT, AVERAGE OF TEN COUNTS AT PITTSFORD, NEW YORK, 1930

Dates of counts	Unsprayed*		Treatment 2		Treatment 1	
			2–2–50 to 10–10–50*		10–10–50 to 2–2–50*	
	A	B	A	B	A	B
	Number	*Number*	*Number*	*Number*	*Number*	*Number*
July 9	...	113	...	118	...	110
July 24	...	144	...	146	...	161
August 11	58	468	23	514	15	630
August 22	120	683	30	759	20	1,134
September 3	310	934	87	1,109	69	1,204
September 10	514	849	124	1,134	105	1,190
September 23	395	421	210	1,072	202	911
October 4	...	...	448	604	541	552

*A = tipburned
B = total.

TABLE 19. AVERAGE YIELD IN BUSHELS PER ACRE IN THE VARIABLE CONCENTRATION EXPERIMENT, 1931–1933

Treatment no.	1931		1932		1933	
	Plots	Average yields per acre	Plots	Average yields per acre	Plots	Average yields per acre
	Number	*Bushels*	*Number*	*Bushels*	*Number*	*Bushels*
Unsprayed	6	230.6	12	179.5	12	212.1
1	21	308.3	21	284.2	24	304.9
2	21	278.7	21	255.3	24	270.5
3	..	....	..	....	24	309.3
4	..	....	..	....	24	299.9
5	..	....	21	261.2	24	282.1

Average gain in bushels per acre of treatment at side of table over treatment at top of table for the series of experiments shown above*

Treatment no.	Treatment no.				
	Unsprayed	1	2	3	4
1	95.2 ±7.3 (30)	.....	.....	.....	.....
2	62.3 ±6.6 (30)	−31.1 ±1.8 (66)	.....	.....	.....
3	97.2 ±1.6 (12)	4.4 ±0.9 (24)	38.8 ±1.1 (24)	.....	.....
4	87.8 ±1.5 (12)	−4.9 ±1.4 (24)	29.4 ±1.4 (24)	− 9.3 ±0.8 (24)	.....
5	76.0 ±6.0 (24)	−22.9 ±0.1 (45)	9.1 ±2.7 (45)	−27.2 ±1.0 (24)	−17.9 ±1.0 (24)

*Figures in parenthesis indicate the total number of comparisons.

the mixture with less free lime may give rise to more soluble copper, it is quite possible that a smaller total quantity of copper sulfate per acre per season may be required with this mixture to obtain maximum yields. In the copper-to-lime-ratio experiments, the total quantity of copper applied per acre was about 65 pounds. Further experiments are needed to test this hypothesis.

EXPERIMENTS TO COMPARE THE EFFICIENCY OF BORDEAUX MIXTURE AND VARIOUS COPPER-LIME DUSTS

Paralleling the spraying experiments, a series of dusting experiments have been made partly to determine the relative value of dusting and spraying and partly to try out different modifications of the dusting mixture to obtain some improvement. The kinds of treatments compared have varied in the different years as shown in table 22 but at one time or another have included the following:

0. Untreated, dusted only with calcium arsenate for the potato beetle.
1. Home-mixed dust (20 parts monohydrated copper sulfate and 80 parts high-calcium hydrated lime by weight).
2. Home-mixed dust (30 parts monohydrated copper sulfate and 70 parts high-calcium hydrated lime by weight).
3. Home-mixed dust (20 parts of monohydrated copper sulfate and 80 parts high-magnesium hydrated lime, known as *finishing lime* and consisting of approximately 30 per cent magnesium hydroxide and 70 per cent calcium hydroxide by weight).
4. Home-mixed 20:80 dust as in No. 1 but heavy applications were made early in the season and the amounts decreased in later applications.
5. Spray (bordeaux mixture 5–5–50) at 400 pounds pressure except in 1929 at 300 pounds.
6. Commercial dust "Niagara Copo-dust" guaranteed to contain 19 per cent monohydrated copper sulfate.
7. Commercial dust "Niagara Spud dust" guaranteed to contain 19 per cent monohydrated copper sulfate.
8. Commercial dust "Niagara D 25" guaranteed to contain 25 per cent monohydrated copper sulfate.

Dusted plots were made somewhat wider than sprayed plots, usually six or eight rows wide, because it was believed that in this way the center rows at least would receive more nearly the normal amount of drift dust than if narrower strips were dusted. At all times the dusts were applied before 7 a. m. while the plants were moist with dew. In some cases dust applications were delayed several days because of the absence of dew. This insistence on dust applications when the leaves were moist is believed to have contributed largely to the success of the dusting in these experiments. This assumption is based on the work of Streeter, Mader, and Kokoski (1932) who showed that lime carbonates rapidly under certain conditions, thus becoming incapable of combining with copper sulfate to form bordeaux mixture.

The varieties of potatoes used were as follows: in the 1929 experiment Heavy Weight; for 1930 and experiment II, 1933, Number 9; and for all other experiments, Rural Russets.

COMPARISON AS TO ADHESION OF COPPER

The outstanding difference in adhesion of copper to be found in this series of tests is between the spray and the various dusts. Although equal amounts of copper were applied by dusting and by spraying, after a few days and especially toward the end of the season more copper was found on the sprayed plants than on the dusted plants (table 20). During the first two years of the tests it appeared that the copper in the commercial dusts adhered better than in home-mixed dusts but such differences tended to disappear during the last two years perhaps because air-separated lime became available and was utilized for dusting. Reducing the lime content of the dust, did not affect the relative adhesiveness of the copper to any measurable extent.

EFFECTS OF DUST AND SPRAY ON GROWTH OF PLANTS

Total number of leaflets per plant

If the growth of the plants is judged by this criterion, the plants in all of the plots appeared to start about evenly but gradually the dusted and sprayed plants drew ahead of the unsprayed with the sprayed plants reaching the largest size and with the dusted plants intermediate between the sprayed and check plots (table 21).

Total number of tipburned leaflets per plant

In a similar way differences developed in the number of tipburned leaflets (table 21). They appeared earlier and increased in number more rapidly on the unsprayed plants than on the dusted and the sprayed plants, which appeared about equally affected early in the season. As the end of the season approached, the plants in the check plots were dead and those in the treated plots began to die; the sprayed plants seemed to have a distinct advantage, remaining green longer and showing fewer tipburned leaflets, so that larger yields were anticipated in these plots.

COMPARISON OF DUSTS AND SPRAYS ON FINAL TUBER YIELDS

The average final tuber yields, presented in table 22 for the seven experiments in five years, are not easily summarized. Some of these treatments were used in only one and others were used in several experiments. Only one treatment, the 20:80 home-mixed copper-lime dust, was used in all experiments. Thus in the part of table 22 giving average differences in yields between each pair of treatments, these differences are not always consistent with each other. In 1929, frost injury occurred in the field distributed very unevenly, favoring the untreated plots, so that the gains in yields for the treated plots were lower than they would otherwise have been.

Comparisons can perhaps best be made with the 20:80 home-mixed dust (treatment 1) since this treatment was used in all experiments and shows an average gain in yield over the untreated of 50.5 bushels per acre for the whole series, even in the absence of late blight throughout the period. On the average, the plots sprayed with bordeaux mixture varied from those treated with the home-mixed dust by only 1.4 bushels with a standard error of 4.9, indicating that this small difference is not significant. Although the

commercial dust ("Copo Dust") gave an average yield about five bushels higher than did the home-mixed dust, this difference also does not appear to be significant because the error is larger than the difference. In only one experiment (1930) out of the six did the commercial dust appear to be decidedly better. In the others the average differences between commercial and home-mixed dust were all less than five bushels per acre and twice in favor of the home-mixed dust. Therefore, there seems to be no good reason for using factory-mixed dust unless it is available at a cost as low as for the home-mixed dust.

Attempts made during the past two years to improve dusting mixtures and methods of application seem to have been successful as judged by the yields obtained. Treatment No. 4 in 1932, which gave the highest average yield for the experiment in that year consisted of larger quantities of dust per acre per application (64 pounds instead of 36 to 38 as on the other plots). In 1933, experiment I, treatment 4 consisted of heavier applications early in the season with decreasing amounts in subsequent applications and again gave the highest yield.

The yield results of treatment 3 are also interesting. The mixture was a 20:80 copper-lime mixture but made up with a high-magnesium lime (known as finishing lime) and containing about one half as much magnesium as calcium. As the magnesium oxide takes no part in making bordeaux mixture it could act as an inert filler or perhaps it might act as a direct stimulant to the plants if the soil was deficient in magnesium which there is reason to believe is not the case. In the two experiments in which the high-magnesium lime was used in preparing the dust mixture in 1933, better yields were obtained than by using the high-calcium lime in the same proportions. Approximately as high yields were obtained, however, by using the high calcium lime but reducing the amount of lime in the mixture (i. e. the 30:70 copper-lime dust) indicating that the benefit obtained by using the high-magnesium lime was due to the reduction in the excess of active lime in the mixture.

DISCUSSION OF THE RESULTS OF EXPERIMENTS COMPARING VARIOUS DUSTS WITH EACH OTHER AND WITH BORDEAUX MIXTURE

When the yield results in these experiments are compared with the data on the growth of plants and the tipburn control, it is evident that there are certain rather unexpected results to be explained. The plots sprayed with bordeaux mixture have consistently produced measurably larger plants that lived longer and had less tipburn than the dusted plots had but have yielded no more, and frequently less, than the dusted plots. The tubers of the sprayed plots have also been more uneven in size and shape than those from the dusted plots. This interpreted in the light of other spraying experiments would seem to indicate that on the sprayed plots too much copper had been applied, particularly, late in the season, which slightly overstimulated growth of tops at the expense of tuber growth.

At the same time, the different rate of dusting tried in 1932 and 1933, indicate that potatoes responded to larger applications of copper in dust form than in the form of spray. This is perhaps to be expected since it has been shown that the copper does not adhere so well when applied in dust form as when applied as a bordeaux spray. When the same amount was

applied, the amounts found by copper tests on the leaves of dusted plants has varied from 40 per cent to 80 per cent of that found on sprayed plants or, on the average, about two-thirds as much copper was retained from the dusting as from the spraying.

Thus the difference in adhesion between dust and spray makes it impossible to obtain the optimum amount on the vines by applying the same amount of copper per acre as dust and as spray. About one-half more on the average would be required as a dust to obtain the same amount on the leaves as with a spray.

From these experiments it may be concluded that, at least under conditions encountered at Pittsford during these years, as good results were obtained by dusting as by spraying. To obtain these results careful attention was given to dusting conditions, frequently involving a delay of an application for several days until conditions were favorable. More copper should be applied per acre in the form of dust than in the form of spray to obtain maximum yields.

The indications are that the amount of lime in the dust mixture can be reduced either directly or by using a lime containing considerable amounts of inactive magnesium. This should be done with caution because there may be danger of burning the plants under some conditions. Several years' experience, on which to base recommendations, is desirable.

GENERAL SUMMARY

Evidence accumulated in experiments conducted over a five-years period (1929–1933) in western New York showed that spraying and dusting potatoes of the Rural variety are profitable practices even when late blight (caused by *Phytophthora infestans*) does not occur. In 1933 only, did late blight occur in these fields, and then only on the check plots so late in the season that the damage was very slight.

TABLE 20. COMPARISON OF THE ADHESION OF THE COPPER APPLIED IN THE FORM OF SPRAY AND DUST IN THE EXPERIMENT AT GEORGE SCHOEN'S FARM, PITTSFORD, NEW YORK, 1930

Date of applications	Date of samples	Quantities of copper on 100 grams of green leaves			
		Bordeaux spray 5–5–50, 100 gal. per acre	Home mixed dust 20–80 38 lbs. per acre	Spud dust 20–80 38 lbs. per acre	Copo-dust 20–80 38 lbs. per acre
		Milligrams	*Milligrams*	*Milligrams*	*Milligrams*
July 5	July 5	40	40	42	37
	July 12	17	8	10	15
July 15	July 15	47	42	49	49
	July 22	22	10	12	17
July 24	July 24	57	45	47	59
	Aug. 2	45	16	22	32
Aug. 12	Aug. 12	75	48	52	60
	Aug. 16	57	22	30	42
Aug. 18	Aug. 18	92	55	65	72
	Aug. 25	70	28	37	52
Aug. 26	Aug. 26	112	60	72	87
	Sept. 4	45	18	22	34
Sept. 5	Sept. 5	95	39	52	62
	Sept. 10	67	29	40	52
Sept. 11	Sept. 11	102	52	72	82
	Sept. 20	63	30	49	57
Sept. 22	Sept. 22	107	63	82	97
	Oct. 8	82	18	32	42

TABLE 21. AVERAGE NUMBER AND CONDITION OF LEAFLETS ON PLANTS IN PLOTS IN THE SPRAY AND DUST EXPERIMENT 1930–31, AVERAGE OF TEN COUNTS

1930 experiment

Dates of counts	Unsprayed*		Copo-dust*		5–5–50 bordeaux*	
	A	B	A	B	A	B
	Number	*Number*	*Number*	*Number*	*Number*	*Number*
July 10	...	54	...	64	...	60
July 26	...	138	...	193	...	201
Aug. 2	...	210	...	305	...	315
Aug. 11	52	305	21	400	17	416
Aug. 27	200	365	54	515	51	563
Sept. 8	122	212	51	352	48	372
Sept. 19	270	375	102	452	92	534
Sept. 29	409	430	209	530	180	608
Oct. 4	...	...	310	575	240	635
Oct. 10	...	...	545	565	329	630

1931 experiment

Dates of counts	Unsprayed*		Copo-dust*		Home-mixed*		5–5–50 bordeaux*	
	A	B	A	B	A	B	A	B
	Number	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*
July 10	...	119	...	115	...	118	...	115
July 21	...	215	...	225	...	229	...	223
Aug. 5	33	550	16	557	16	575	15	575
Aug. 18	180	696	74	777	75	774	76	782
Sept. 1	286	742	96	846	100	842	91	859
Sept. 10	408	855	193	1,080	196	1,186	174	1,208
Sept. 22	324	331	301	718	312	706	270	779
Oct. 2	...	...	431	462	414	464	429	517

*A = tipburned
B = total.

Early blight (caused by *Alternaria solani*) was not of any measurable importance in any of the experiments.

Flea-beetles *(Epitrix cucumeris)* were present in nearly all of these experiments and caused some damage to a few of the unsprayed plants. The amount of injury was moderate, all sprayed and dusted plants showing fewer punctures than the unsprayed. No great differences in leaf punctures were found between the plots sprayed at different pressures and those which received different amounts of material.

Colorado potato beetles were eliminated from consideration by spraying all plots, including checks, with calcium arsenate.

The control of leaf-hopper-burn caused by the potato leaf-hopper *(Empoasca fabae)*, generally recognized as one of the most important factors in increasing yields, was found to explain only partially the increases in yields obtained in the experiments. Increased pressures up to 400 pounds resulted in a decrease in the amount of tipburn. No additional reduction occurred when more than 36 pounds of copper sulfate to the acre per season, in the form of bordeaux mixture, was applied at 400 pounds pressure. Increases in yields, however, occurred if the amount of copper sulfate applied was increased up to approximately 75 pounds to the acre per season.

It is believed that some of the gain in yields was due to the effect which copper in the form of bordeaux mixture exerts on the potato plant.

TABLE 22. AVERAGE YIELDS IN BUSHELS PER ACRE IN THE SPRAY AND DUST EXPERIMENTS, 1929 TO 1933

Treatment	Treatment no.	1929		1930		1931 Exp. I		1931 Exp. II		1932		1933 Exp. I		1933 Exp. II	
		Pounds of copper sulfate applied per acre per season													
		68.6		72.8		70.0		70.0		60.6		63.8		63.8	
		Plots	Yields	Plots	Yields	Plots	Yields	Plots	Yields	Plots	Yields	Plots	Yields	Plots	Yields
		Number	*Bushels*	*Number*	*Bushels*	*Number*	*Bushels*	*Number*	*Bushels*	*Number*	*Bushels*	*Number*	*Bushels*	*Number*	*Bushels*
Untreated	0	2	206.4	4	203.7	6	165.9	.	....	12	230.1	6	164.4	..	....
20–80 copper-lime, home-mixed, with high-calcium lime	1	6	225.7	6	267.5	9	213.7	6	205.7	21	277.9	9	220.3	12	247.5
30–70 copper-lime home-mixed, with high-calcium lime	2	.	....	.	....	.	....	.	....	..	....	9	229.6	..	....
20–80 copper-lime home-mixed, with high-magnesium lime	3	.	....	.	....	.	....	.	....	..	....	9	232.3	12	264.5
20–80 copper-lime home-mixed, with high-calcium lime and heavy applications	4	.	....	.	....	.	....	.	....	21	294.0‡	9	249.5§	..	....
5–5–50 bordeaux mixture at 400 pounds pressure	5	6	209.0	6	285.7*	9	207.4	6	194.7	21	279.2	.	....	..	....
20–80 copper-lime factory-mixed "Copo-dust"	6	6	220.9	6	311.5	9	211.0†	6	206.7†	21	281.3	.	....	12	249.9
20–80 copper-lime factory-mixed "Spud dust"	7	.	....	6	299.2	.	....	.	....	..	....	.	....	..	....
Niagara D-25 commercial dust	8	.	....	.	....	.	....	.	....	..	....	9	208.3	12	236.0

Average gains in yield in bushels per acre of treatments at side of table over treatments at top for the series of experiments above||

Treatment no.	Treatment no.						
	Untreated	1	2	3	4	5	6
1	50.5± 5.0 (30)	.....	.....	.....	.....	.....	.....
2	68.9± 5.8 (6)	9.3±4.0 (9)	.....	.....	.....	.....	.....
3	70.0± 3.4 (6)	14.9±2.5 (21)	7.0±4.0 (9)	.....	.....	.....	.....
4	72.5±12.0 (18)	20.0±5.9 (30)	12.5±3.6 (9)	13.0 3.4 (9)	.....	.....	.....
5	49.6± 1.6 (24)	1.4±4.9 (48)	.....	.....	−14.8±1.5 (21)	.....	.....
6	57.1± 1.6 (24)	4.5±6.0 (63)	.....	.....	.....	7.0±3.4 (48)	.....
7	95.5± 6.5 (4)	25.2±8.9 (6)	.....	.....	.....	4.5±7.2 (6)	−5.9±9.8 (6)
8	46.9± 1.6 (6)	11.7±0.02 (21)	−28.8±4.8 (9)	−25.3±3.1 (18)	−35.2±3.0 (9)	.....	.....

*Applied 80.0 pounds of copper sulfate per acre per season.
†Applied 61.4 pounds of copper sulfate per acre per season.
‡Applied 84.1 pounds of copper sulfate per acre per season.
§Applied 72.2 pounds of copper sulfate per acre per season.
||Figures in parenthesis indicate number of comparisons.

As regards the relative effectiveness of different pressures at which sprays are applied, maximum yields were obtained at 400 pounds, applying at least 116 gallons to the acre per application. That part of the gain in yields obtained by spraying at higher pressures is due to increased amounts of materials applied was clearly shown. When as much material was applied at 400 as at 600 pounds pressure there was no significant difference in yields. Increasing the amount of material applied at 600 pounds pressure (125 gallons per application) resulted in yields lower than those which were obtained by the use of 116 gallons at the same pressure or even by the use of the 116 gallons at 400 pounds pressure.

The gain in yield at 400 pounds over 200 pounds pressure was large enough to make spraying at the higher pressure profitable. Of 27 comparisons, the gain averaged 38 bushels per acre, which difference is highly significant.

After it was found that not only an increase in pressure but also the use of larger quantities of copper sulfate resulted in higher yields, further experiments showed that the most profitable results were obtained by the use of approximately 75 pounds of copper sulfate to the acre per season, applied at a pressure of 400 pounds. The increase in yields from this treatment over the unsprayed, based on 24 comparisons, amounted to 118.1 bushels, which proved to be highly significant. The use of more than 75 pounds of copper sulfate to the acre per season has resulted in lower yields.

As the amount of copper applied in the form of bordeaux mixture was increased, the foliage development was increased. Apparently this is favorable for tuber formation if it occurs early in the season but heavy applications late in the season stimulated growth of foliage at the expense of tuber formation.

Schedules arranged to apply most of the copper early in the season have consistently resulted in higher yields than have schedules in which the copper was evenly distributed throughout the season (average difference 22.9 bushels per acre) or schedules in which heavy applications were made late in the season (average difference 31.1 bushels per acre). These differences cannot be attributed to differences in the control of early or late blight and probably only to a slight extent to differences in leaf-hopper and flea-beetle control. Under the conditions of these experiments, plants receiving the heavy applications early in the season, reached their maximum foliage development relatively early (about the first of September) and matured a little earlier than plants receiving heavy applications late in the season. In particular, the greater growth of foliage of plants without proportionate tuber development sprayed heavily late in the season seems to be strong evidence that copper exerts a stimulative action upon foliage growth in addition to its protective action against insects and diseases.

While the type of schedule in which most of the copper is applied early in the season has not yet been tried under conditions in which late blight was severe, the indications were in 1933 when blight occurred late in the season, that sufficient copper remained on the foliage from early sprays to prevent infection.

Comparison of bordeaux mixtures made with different kinds of lime showed relatively slight differences. There was no significant difference in adhesiveness or growth of plants but a slight difference in the average yields in favor of high-magnesium lime (finishing lime). This was at-

tributed to the smaller amount of active lime present since the magnesium was believed to be inactive in the formation of bordeaux mixture.

Experiments in which the amount of lime in the mixture was varied confirm this conclusion. The average gain in yield of the 5 ($CuSO_4$ $5H_2O$)–1(CaO)–50 over the 5–2½–50 mixture was 6.1 bushels per acre, over the 5–5–50 mixture 19.3 bushels, and over the 5–7½–50 mixture 28.9 bushels for 42 comparisons in each case. This tendency for the mixtures with smaller excesses of lime to give higher yields is attributed to the greater solubility of copper in these mixtures. Perhaps it is unsafe to recommend a mixture with less lime than the 5–2½–50 mixture since the 5–1–50 contains no excess of lime to allow for errors in weighing or impurities in the lime which occasionally occur and thus might easily give a mixture that would cause burning.

In this series of experiments, in which careful attention was given to selecting suitable times for dust applications, as satisfactory results were obtained by dusting as by spraying. The indications were that more copper should be applied in the form of copper-lime dust than was used in the bordeaux spray, to obtain maximum yields.

With dusting as with spraying, additional gains were obtained by applying a large part of the copper early in the season and by reducing the amount of lime in the mixtures either directly or by using a high-magnesium lime, which contains more inert material.

In spraying experiments it was found that heavy application of copper continued late in the season resulted in tubers uneven in size and shape so that a smaller percentage of No. 1 potatoes were obtained than in plots where a large part of the copper was applied early in the season.

It should perhaps be emphasized that these results were obtained with Russet Rural and Smooth Rural potatoes in western New York, planted rather late in the season as main-crop potatoes. There are indications that these results may not apply to other varieties of potatoes under other conditions, and tests have not yet been made with the same varieties planted early in the season.

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